

Nuclear Power Economics and Need?

David Nicholls

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David Nicholls PrEng, CEng, FSAIEE, MINucl

- Joined Royal Navy in 1971 and qualified as Nuclear Engineer in submarines
- Emigrated to South Africa in 1984 and joined Eskom as Koeberg was being commissioned.
- Developed the PBMR project from 1995 to 2005
- Lead the technical element of Eskom's nuclear procurement from 2007.
- Eskom Chief Nuclear Officer from 2016.
- Retired from Eskom in 2018.
- Appointed as the Chairperson of South African Nuclear Energy Corporation in 2020.
- Chairman of the IAEA Technical Working Group on Light Water Reactors from 2010 to 2016
- Currently the Co-Chair of the IAEA Technical Working Group on Nuclear Power Plant Operations.
- He was a member of WANO's Post-Fukushima Design Review Team from 2012 to 2018.
- He is a Professor of Practice at the University of Johannesburg since 2020.

Topics

- Real Costs of Nuclear Projects
- Impact of CAPEX and NDR
- Can Nuclear be Built Fast Enough?
- Impact of Intermittency on Tariff
- Impact on Carbon Emissions
- Corelation of Electricity and GDP
- What are Small Modular Reactors (SMR)?
- Final Thoughts

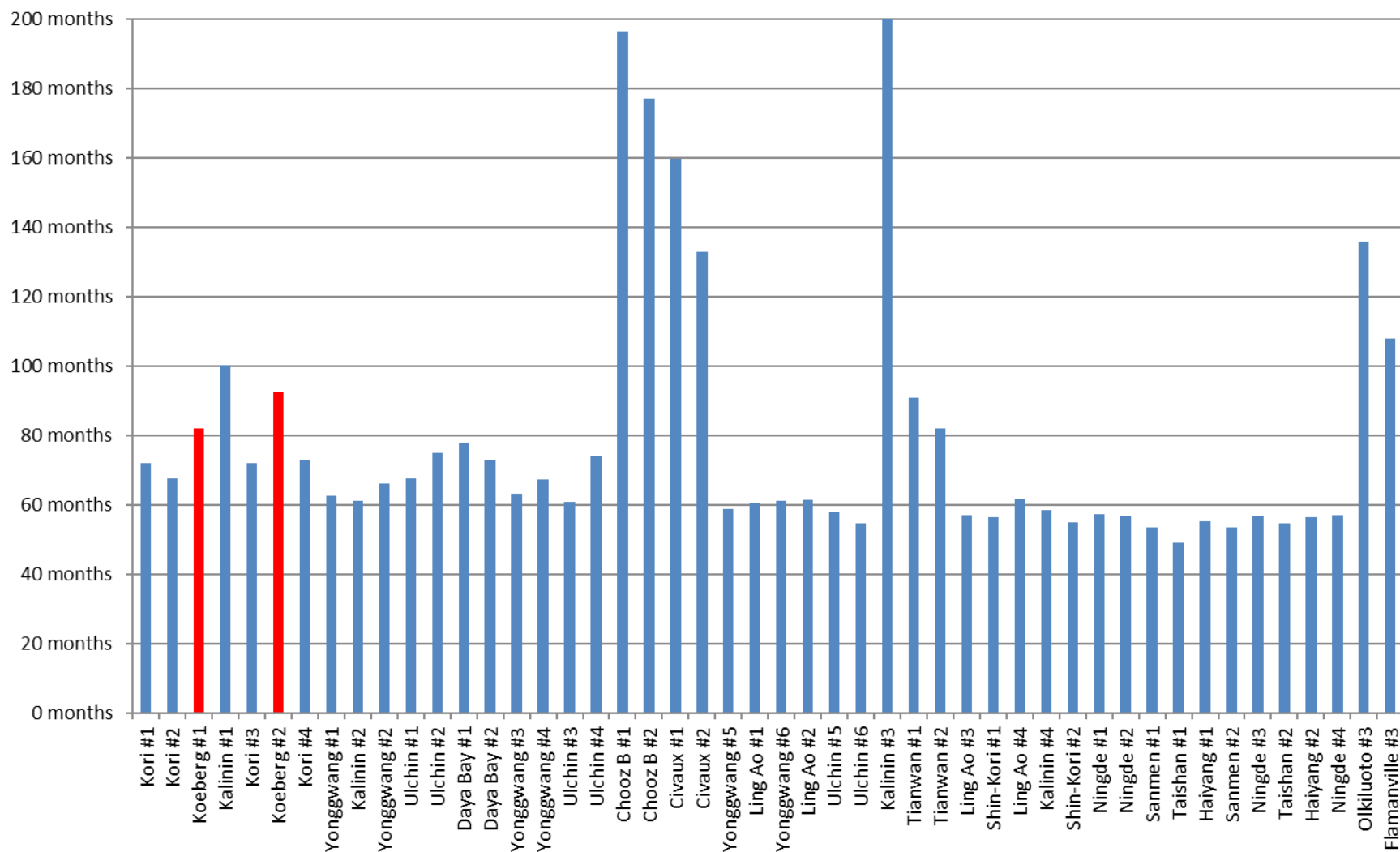
Real Costs of Nuclear Projects

Financial Times - Opinion [Inside Business](#) 27 Jan 2019

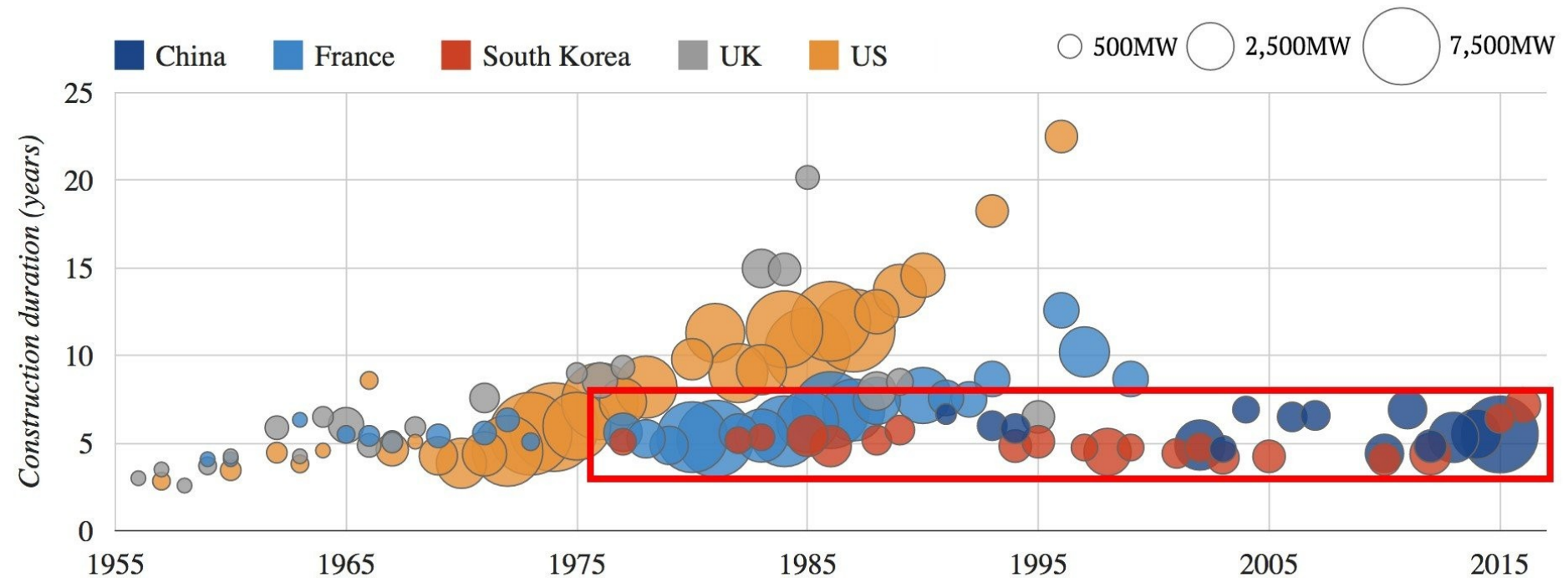
“Nuclear is less costly than you think”

- Analysis for the Energy Technologies Institute (an organisation backed by the government and a number of energy companies) looked at 34 delivered nuclear projects round the world.
- First of a Class in USA/EU
\$9,000-\$12,000/kWe
- 15% > \$5,500/kWe
- 45% \$5,500-\$3,500/kWe
- 40% < \$3,500/kWe

First Concrete to Commercial Operation Sorted by Completion Date



World Experience of Nuclear Construction Times



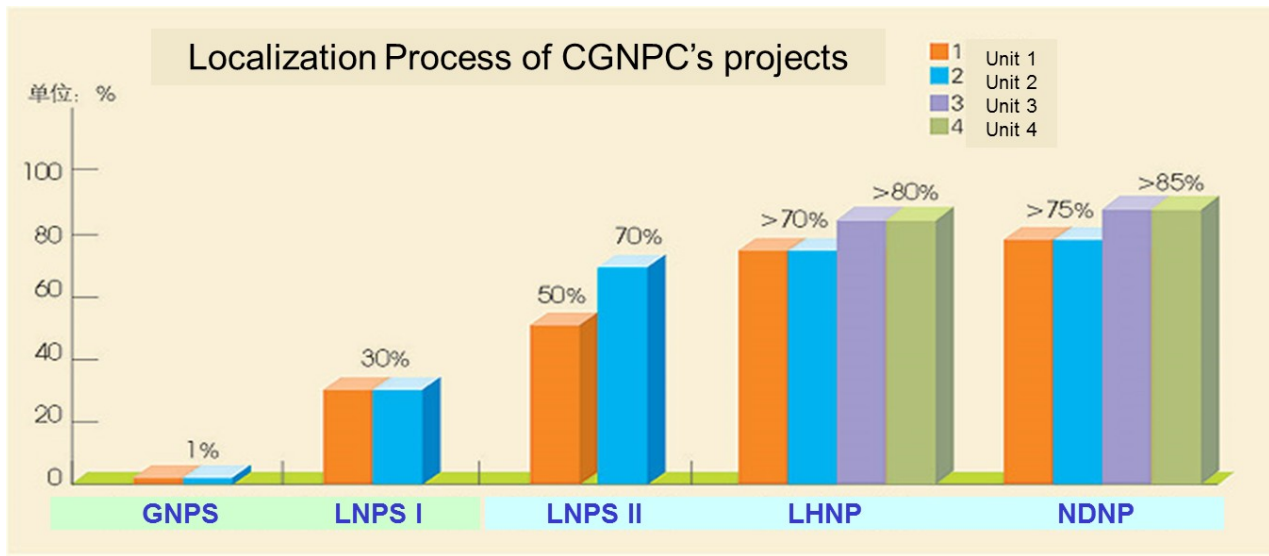
Current Export Contracts

(public statements, various scope including fuel and O&M)

Country	Reactor	Capacity	Cost	\$/kWe
Pakistan	HPR-1000 x 1	1 060MW	\$3bn	\$3 283/kW
India	VVER-1000 x 4	917MW	\$12bn	\$3 293/kW
China	VVER-1200 x 4	1 100MW	\$18bn	\$4 091/kW
UAE	APR-1400 x 4	1 337MW	\$22bn	\$4 114/kW
Belarus	VVER-1200 x 2	1 110MW	\$10bn	\$4 505/kW
Pakistan	HPR-1000 x 2	1 014MW	\$10bn	\$4 734/kW
Turkey	VVER-1200 x 4	1 114MW	\$22bn	\$4 937/kW
Bangladesh	VVER-1200 x 2	1 080MW	\$13bn	\$5 856/kW
Hungary	VVER-1200 x 2	1 100MW	\$14bn	\$6 364/kW
Egypt	VVER-1200 x 4	1 100MW	\$29bn	\$6 534/kW
UK	EPR x 2	1 650MW	\$30bn	\$9 061/kW

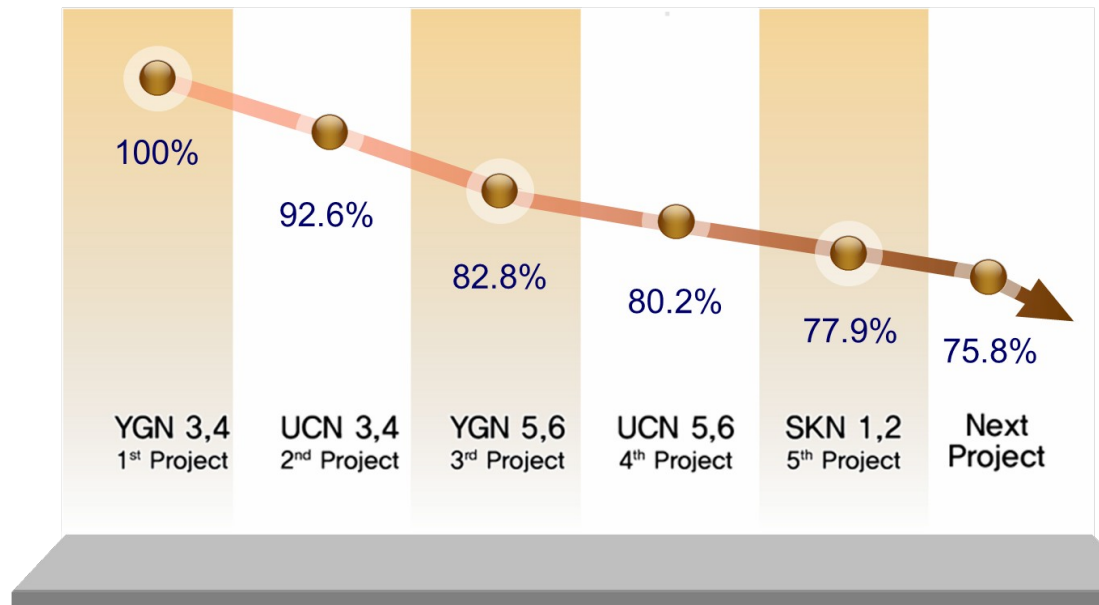
that domestic projects in China, S Korea, Russia and India are quoted as below \$3

Impact of Standardised Fleet Build - Practice



Chinese CPR1000 component localisation over sustained fleet build

S Korean OPR cost reductions in a mature industry due to standardised design



Impact of CAPEX and NDR

Capex & NDR vs. Levelised Cost

Capex exc IDC, incl Owners Cost

Plant Life = 60yrs

Load Factor = 90%

O&M + Fuel = \$20.00/MWh

Capex spend over 72mths

\$2,500/kWe

\$3,000/kWe

\$3,500/kWe

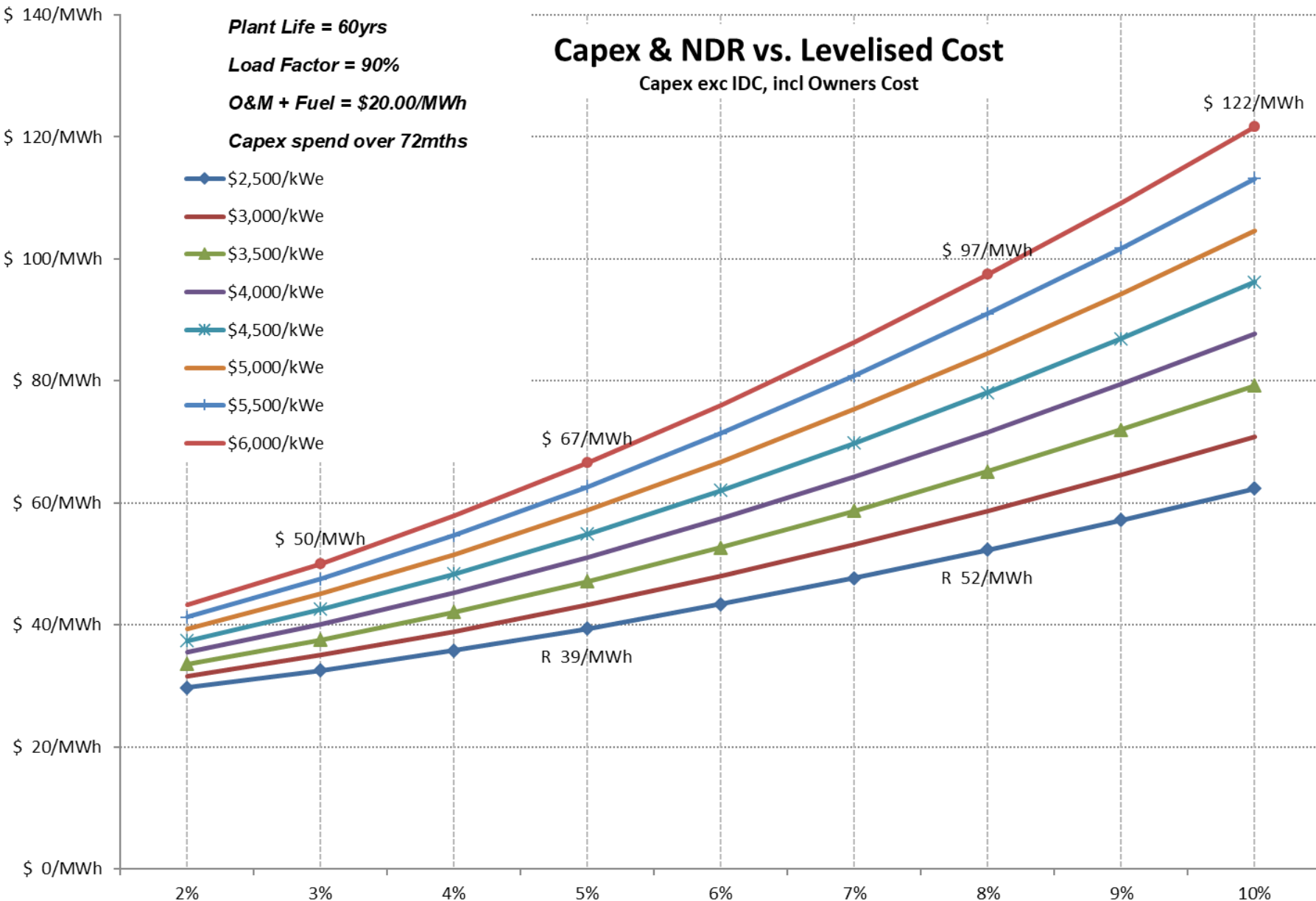
\$4,000/kWe

\$4,500/kWe

\$5,000/kWe

\$5,500/kWe

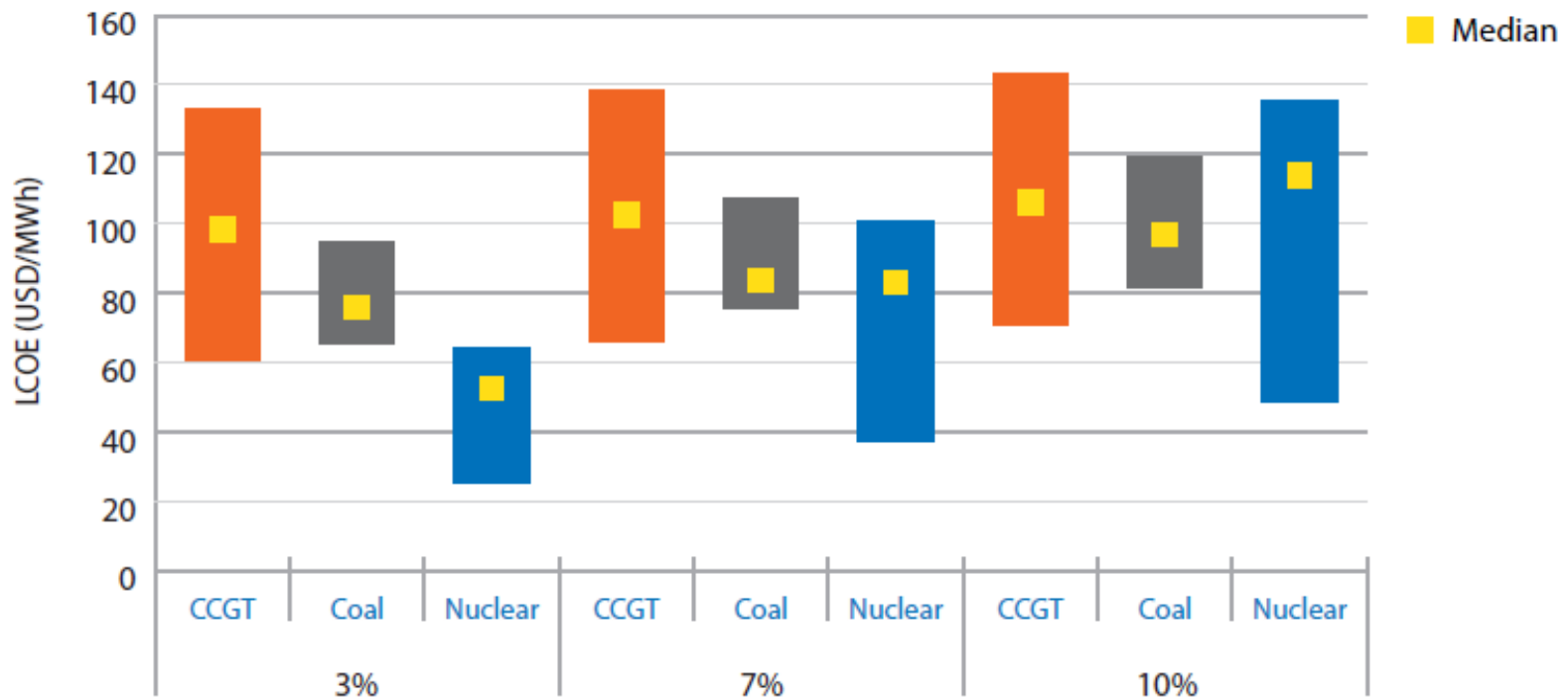
\$6,000/kWe



Projected Costs of Generating Electricity

2015 Edition

Figure ES.1: LCOE ranges for baseload technologies (at each discount rate)



Eskom ECA Financing Rates – FY 2020

	Currency	Security number	Interest rate		Nominal		Maturity date	Group Carrying value		Company Carrying value	
			2020	2019	2020	2019		2020	2019	2020	2019
			%	%	m	m		Rm	Rm	Rm	Rm
Export credit facilities ⁵								32 746	31 782	32 746	31 782
	JPY	n/a	1.49	1.58	2 469	4 944	May 22	406	644	406	644
	EUR	n/a	1.25	0.89	35	50	Sep 23	658	775	658	775
	EUR	n/a	0.57	0.66	7	9	Jul 24	140	142	140	142
	EUR	n/a	4.74	4.73	604	723	Jan 27	11 330	11 153	11 330	11 153
	EUR	n/a	2.48	2.49	491	575	Jul 27	9 100	8 771	9 100	8 771
	ZAR	n/a	9.06	9.35	1 528	1 765	Jul 27	1 419	1 640	1 419	1 640
	USD	n/a	2.32	2.32	583	641	Mar 31	9 693	8 657	9 693	8 657

Can one get funding?

Russia to lend Egypt \$25 billion to build nuclear power plant

CAIRO (Reuters) - Russia will loan Egypt \$25 billion to finance building and operating a nuclear power plant in Egypt, the official gazette said on Thursday.

Egypt and Russia signed an agreement on Nov. 19 for Russia to build Egypt's first nuclear power plant in Egypt and to extend Egypt a loan to cover the cost of construction.

It was not clear at the time what the deal was worth, but Egypt's president Abdel Fattah al-Sisi said the loan would be paid off over 35 years.

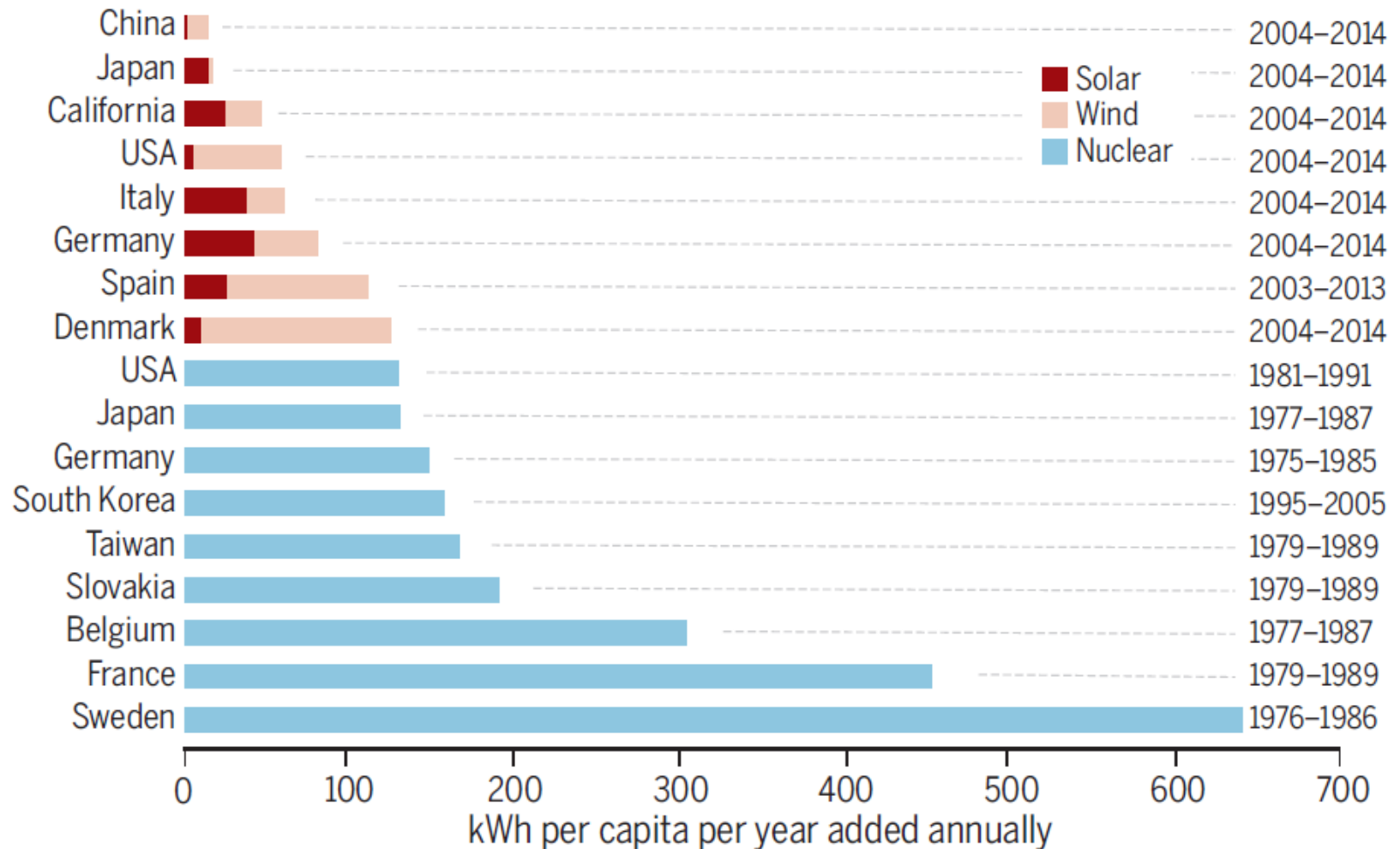
Egypt will pay an interest rate of 3 percent annually, according to the country's official gazette. Installment payments will begin on Oct. 15, 2029.

"The loan will be used by the Egyptian side for a period of 13 years between 2016-2028 ... the Egyptian side will repay loan amounts used over 22 years in 43 installments," the gazette said.

Standard & Poor's rates Egypt at B and RSA at BB-

Can Nuclear be Built Fast
Enough?

How fast can nuclear be deployed?



100%

Electricity Production in France 1960-2015

(Data from World Bank)

90%

80%

70%

60%

50%

40%

30%

20%

10%

0%

Nuclear Energy

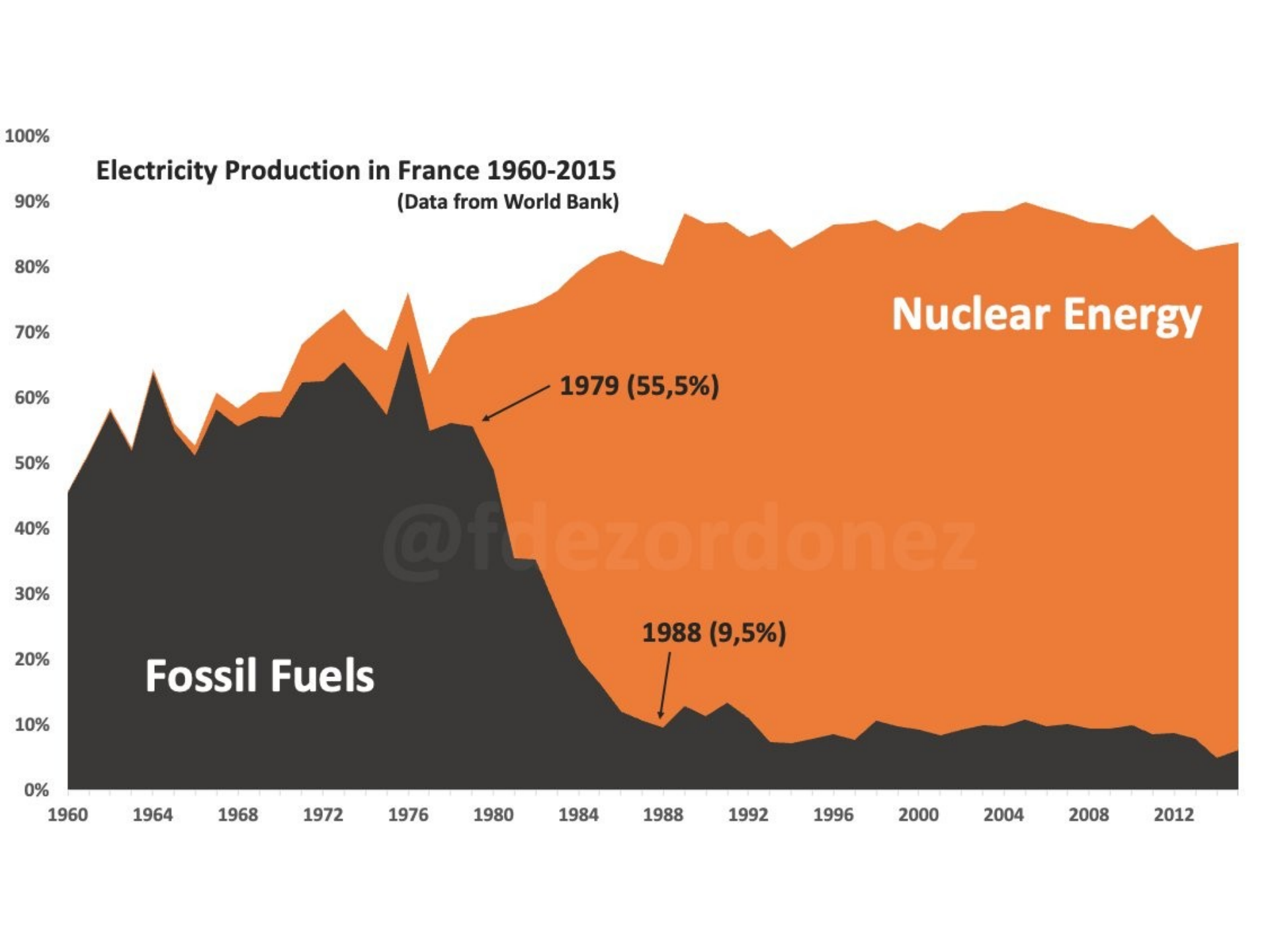
1979 (55,5%)

1988 (9,5%)

Fossil Fuels

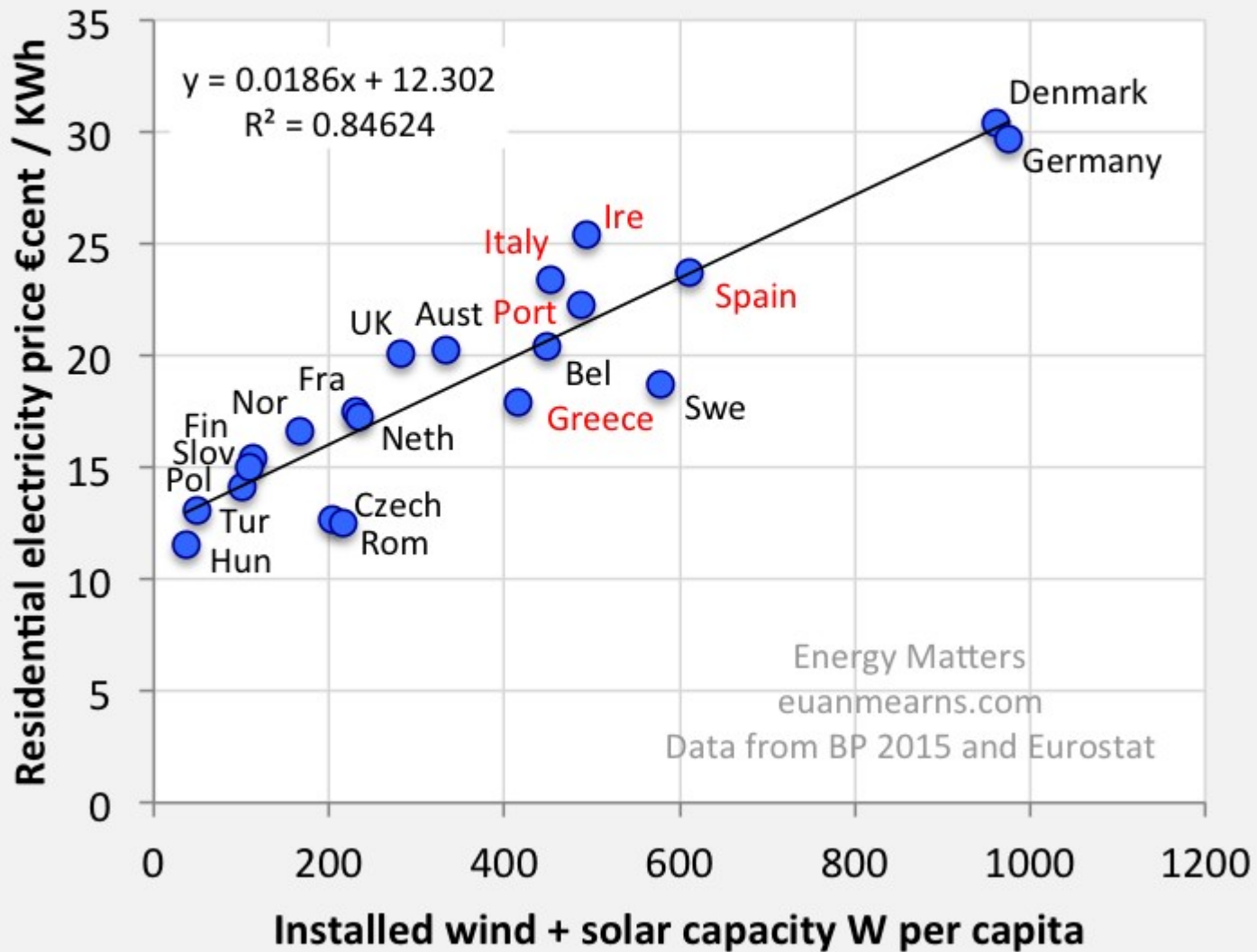
1960 1964 1968 1972 1976 1980 1984 1988 1992 1996 2000 2004 2008 2012

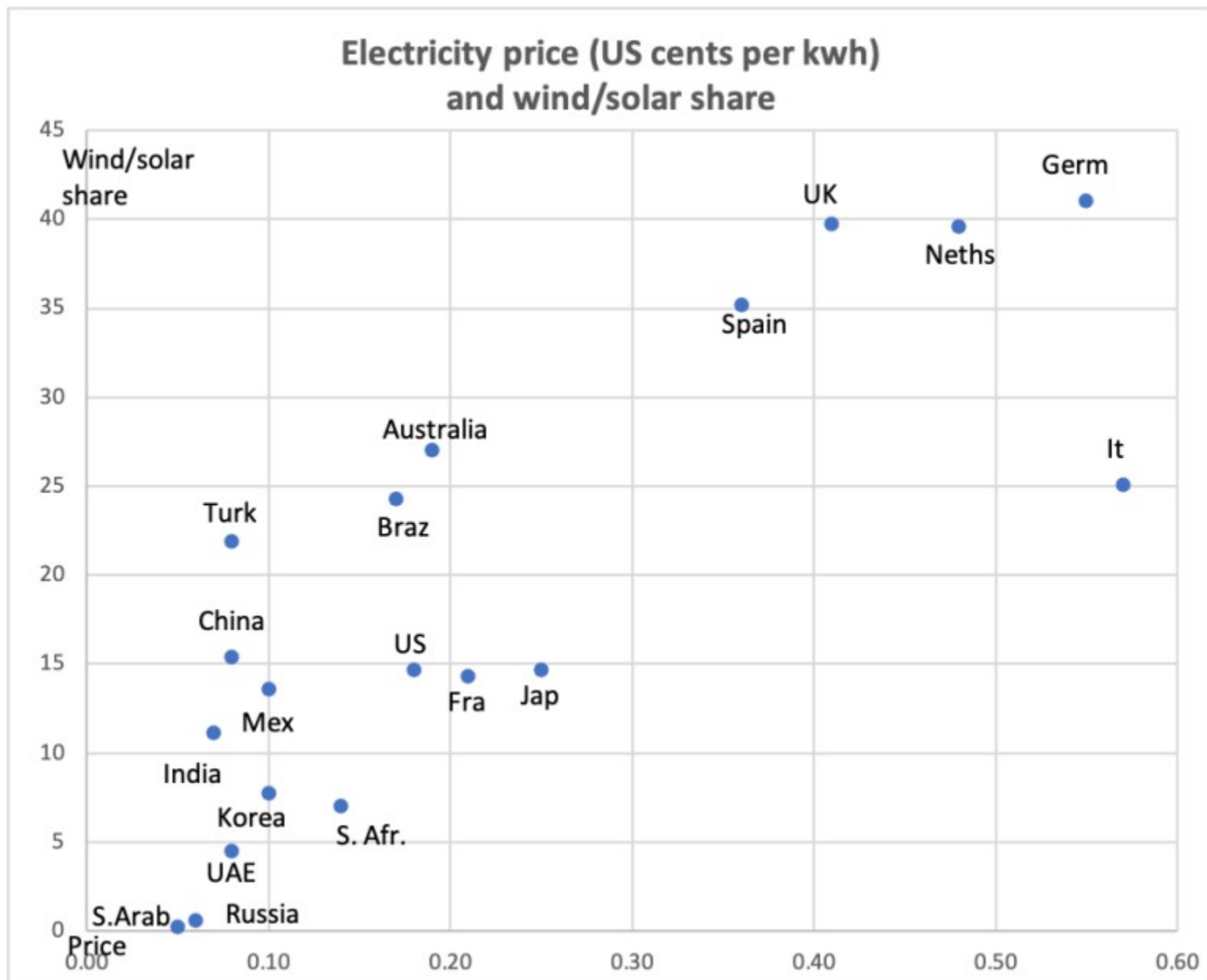
@fdezordonez



Impact of Intermittency on Tariff

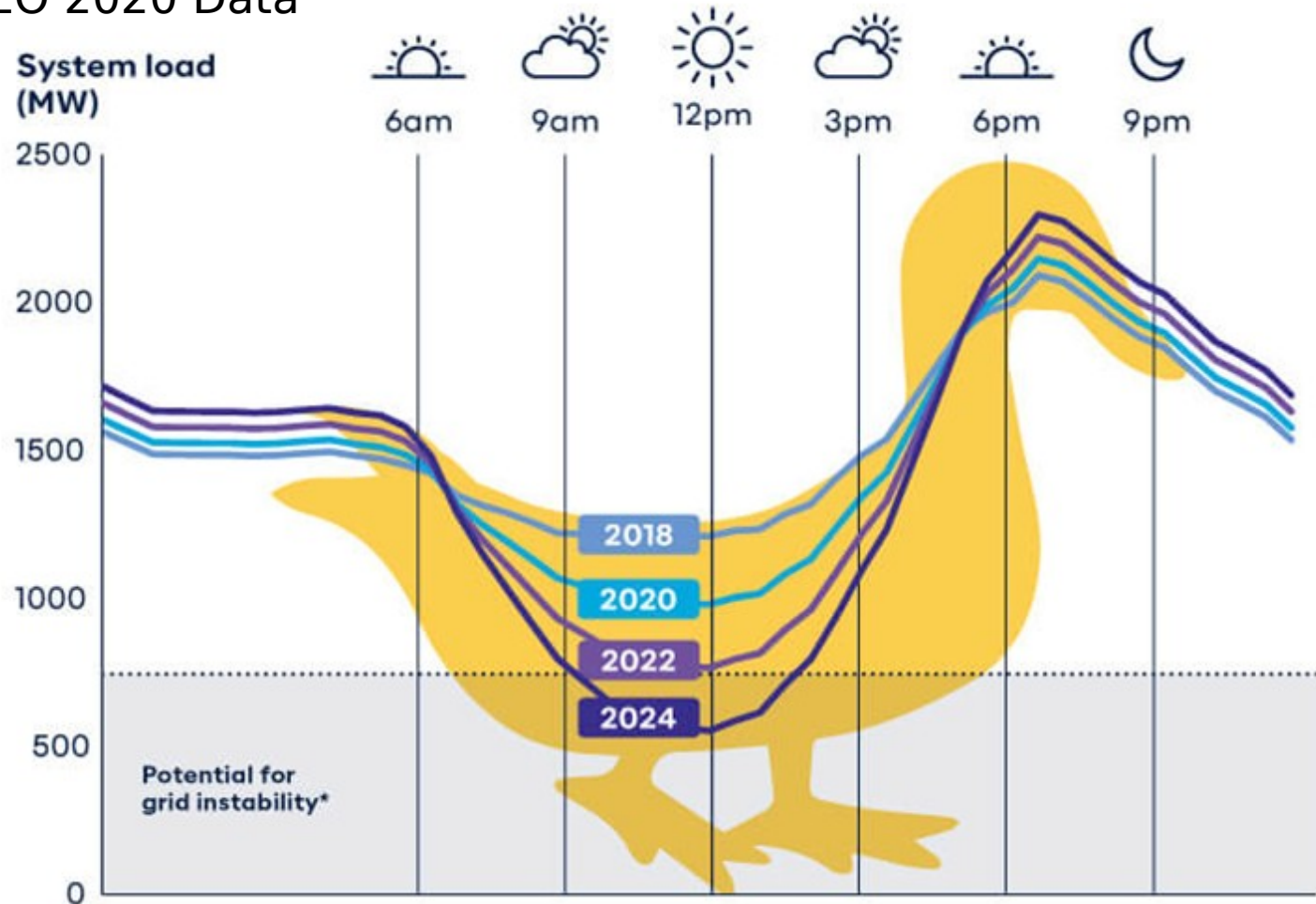
Europe Electricity Price v Installed Wind + Solar Capacity





Western Australia “Duck Curve”

AMEO 2020 Data

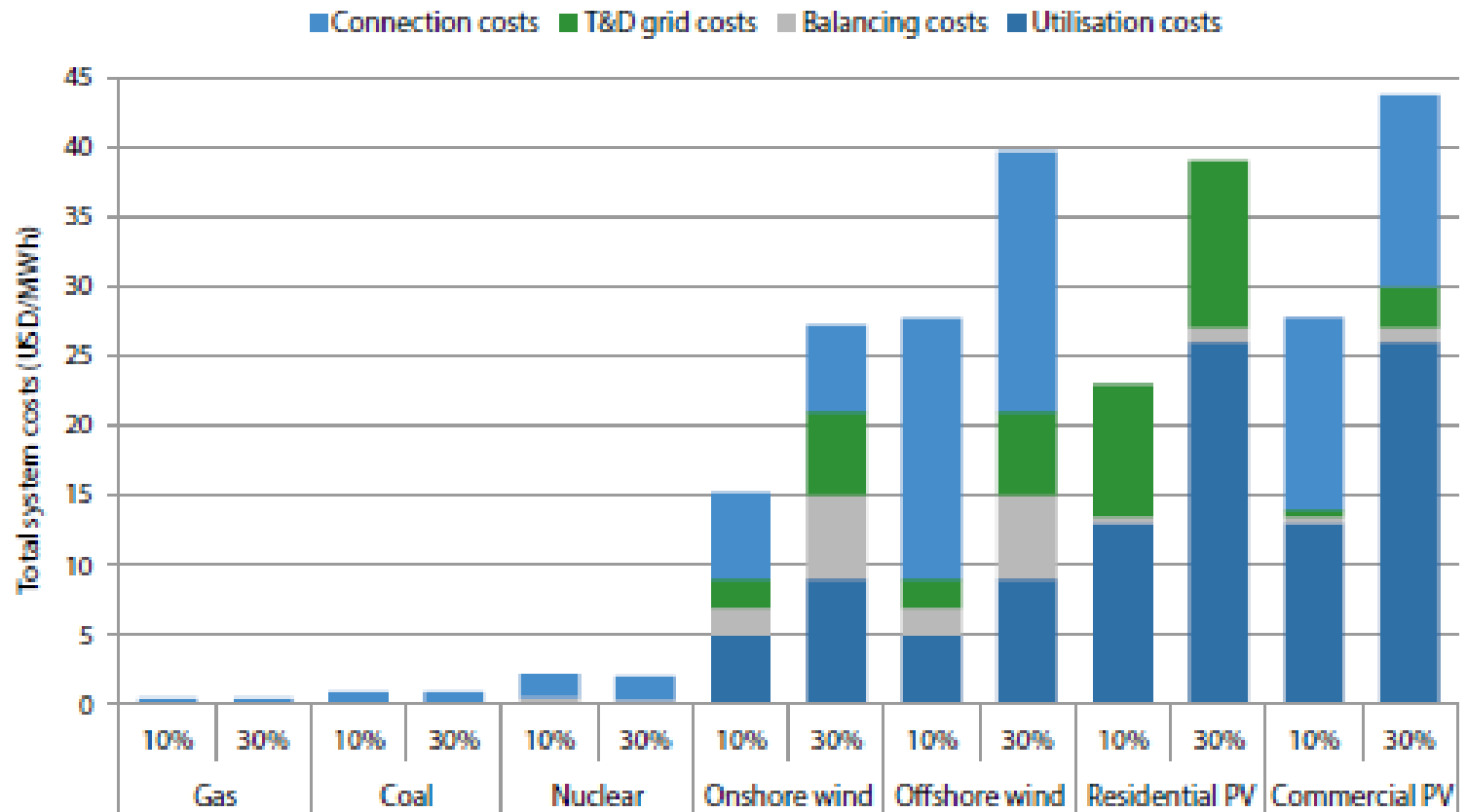


The Full Costs of Electricity Provision



© OECD 2018
NEA No. 7441

Figure ES.3: **Grid-level system costs of selected generation technologies for shares of 10% and 30% of VRE generation**

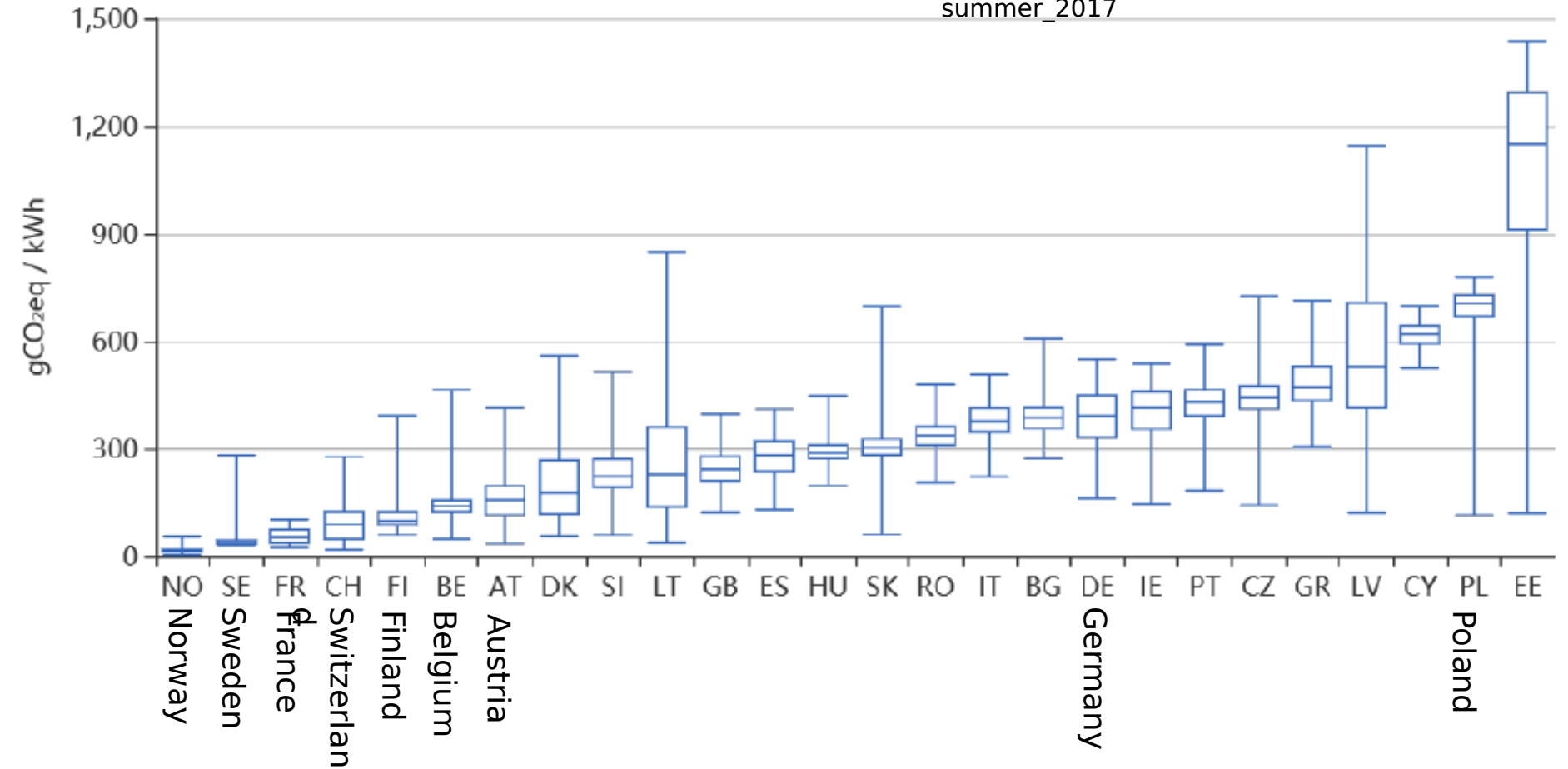


Impact on Carbon Emissions

Carbon intensity of European states, ranked by median value, summer 2017

Statistical analysis with hourly granularity

https://pro.electricitymap.org/reports/summer_2017



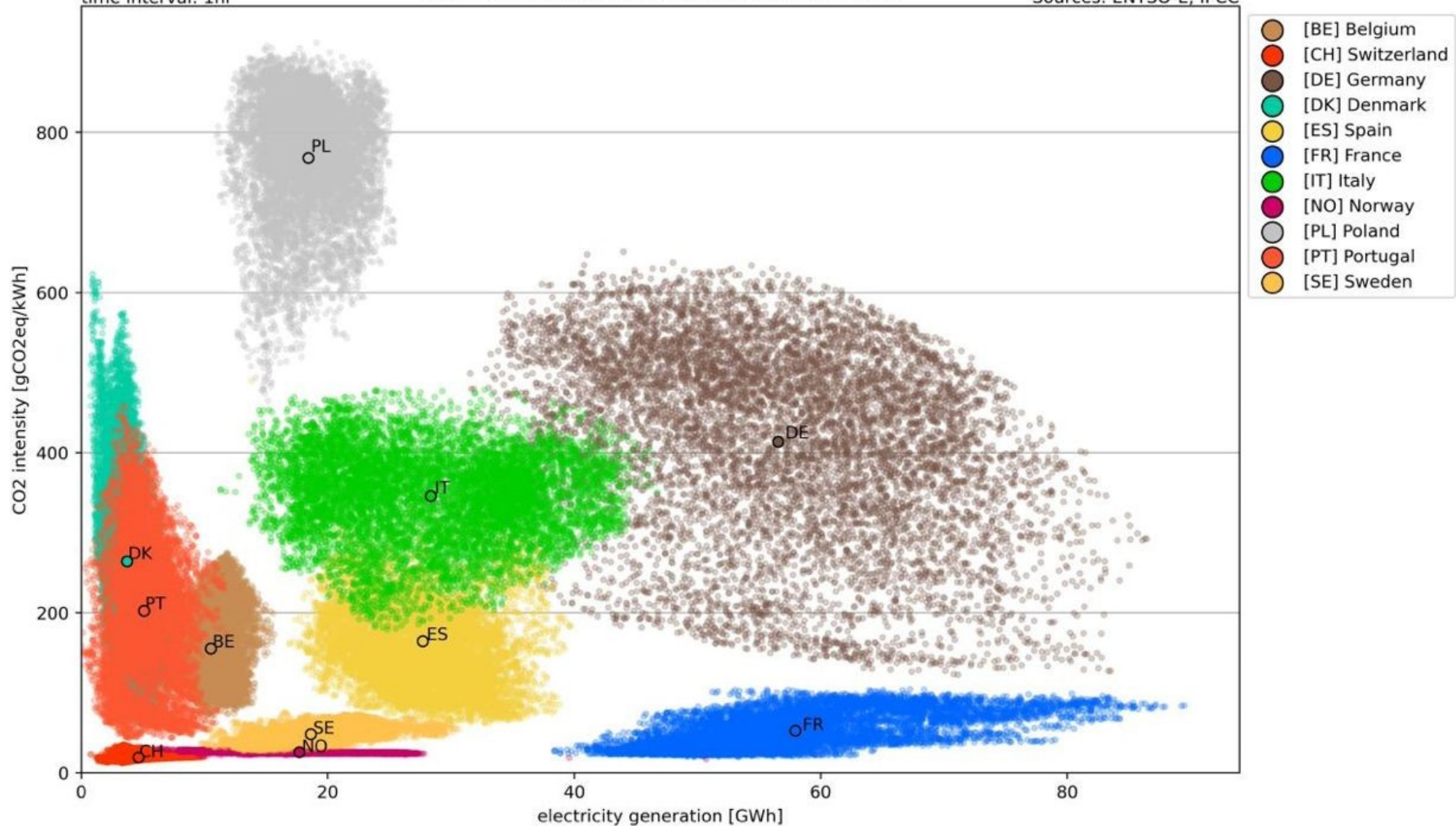
electricity generation (abscissa) compared to CO2 intensity (ordinate)

From 01/01/2021, 00:00 to 01/01/2022, 00:00

@BotElectricity v0.7

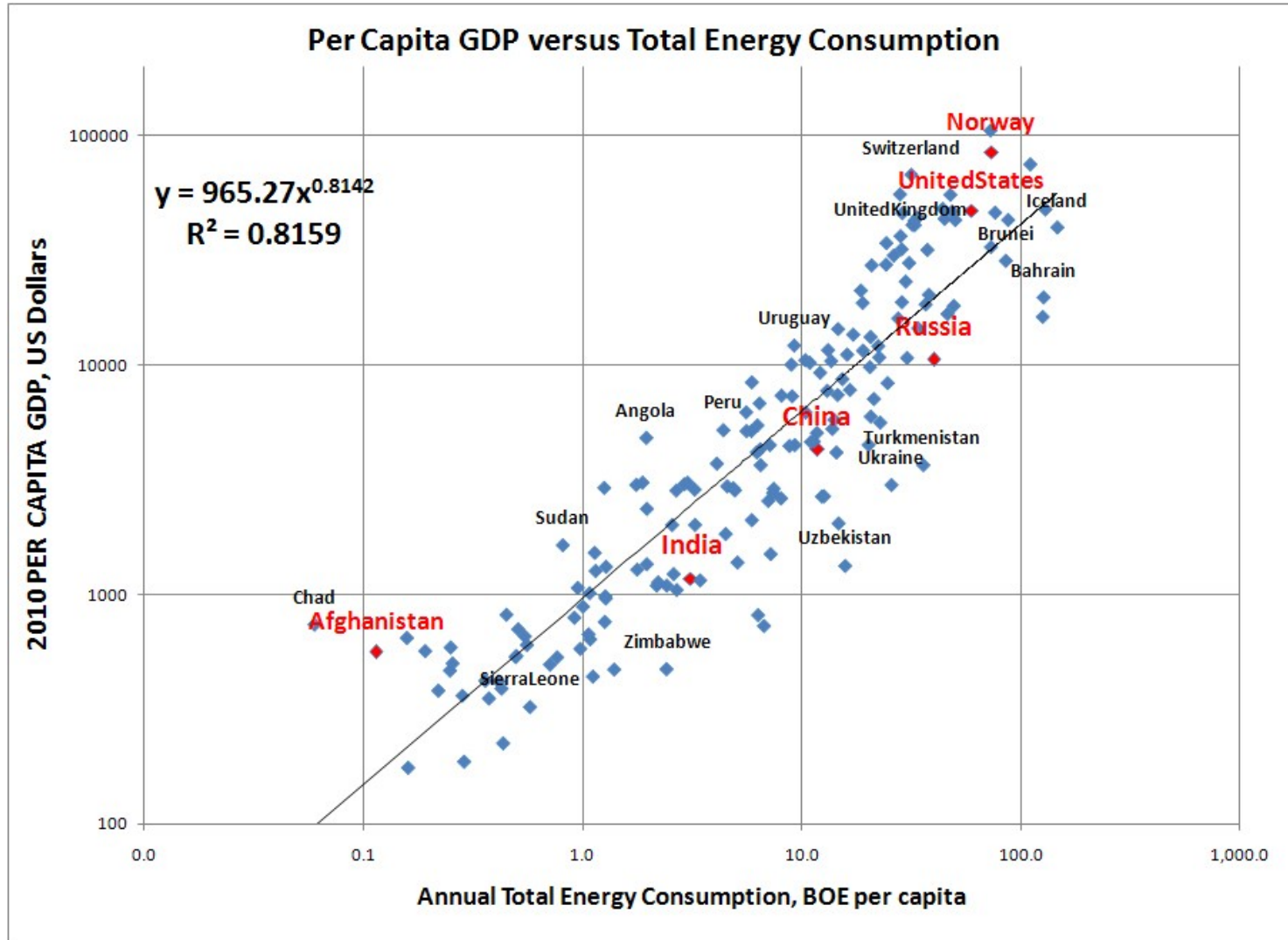
Sources: ENTSO-E, IPCC

time interval: 1hr



Correlation of Electricity and GDP

Abundant and reliable electricity for economic growth



What are Small Modular Reactors? (SMRs)

What Are the Aims of SMRs?

- **SMR = Small Modular Reactor < 300 MW (some are now 500 MW or more)**
- **Manufactured under controlled conditions in factories**
-economy of scale
- **Three types: Large grid, Small Grid, Off-Grid**
- **Passive and inherently safe**
- **Reduced operating and maintenance costs**
- **Carbon free baseload, synergy with renewables**
- **Centralized remote operation of multiple SMRs with single operating team**

Small Modular Reactor Status

(over 70 projects in development)

DesignC	Country	Type	Status	Power
KLT-40s	Russia	Water Cooled	In Operation	35 MWe
HTR-PM	China	Gas Cooled	In Operation	210 MWe
Carem-25	Argentina	Water Cooled	In Construction	32 MWe
ACP100	China	Water Cooled	Construction started 2021	125 MWe
Brest-300	Russia	Lead Cooled	Construction Started 2021	300 MWe
NuScale	USA	Water Cooled	In Design	60MWe
SMART	S. Korea	Water Cooled	In Design	107MWe
VK-300	Russia	Water Cooled	In Design	355MWe
BWRX-300	USA/ Japan	Water Cooled	In Design	280MWe
RITM200	Russia	Water Cooled	In Design	53MWe
Xe-100	USA	Gas Cooled	In Design	83MWe
4S	Japan	Liquid Metal	In Design	10MWe
SVBR	Russia	Lead Bismuth	In Design	100MWe

Actual Small Modular Reactors

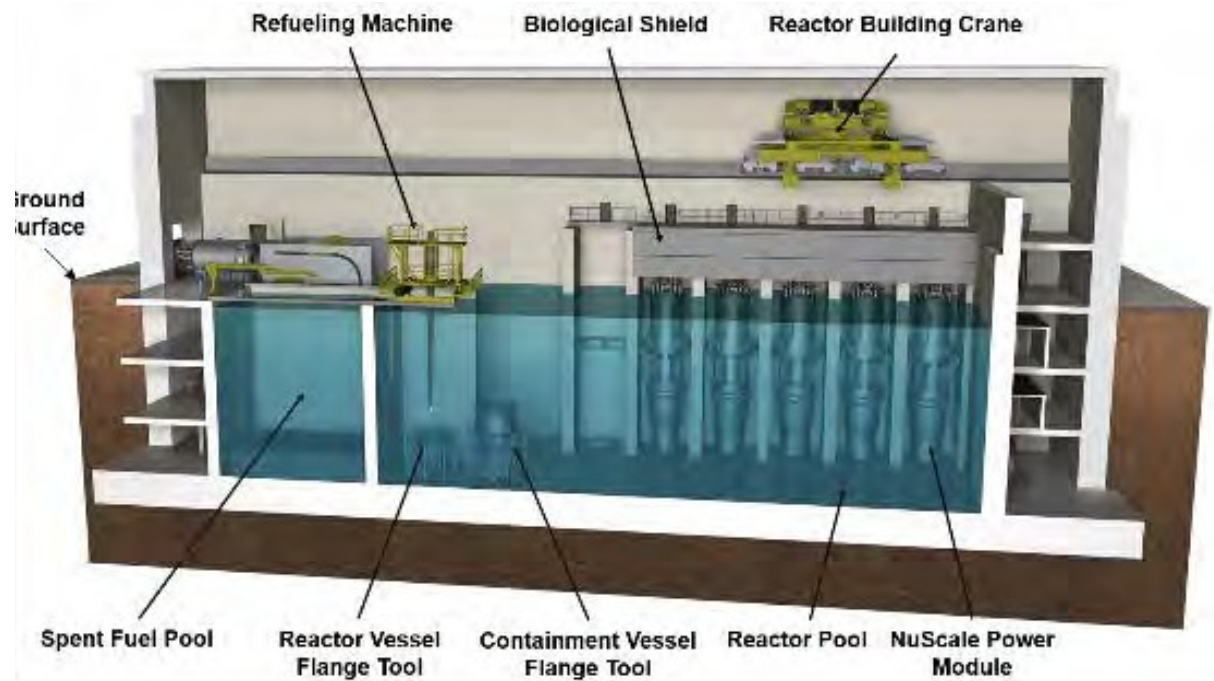
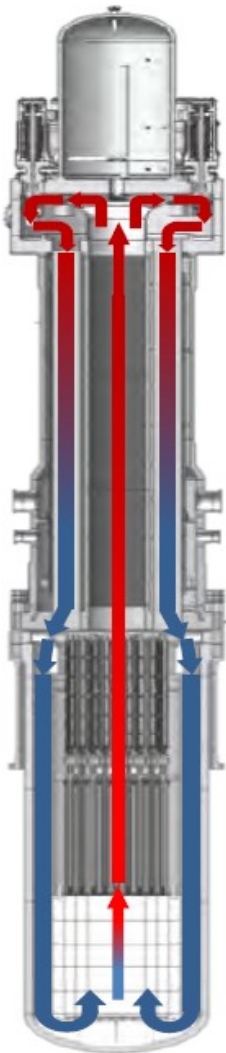


Akademik Lomonosov – FNPP

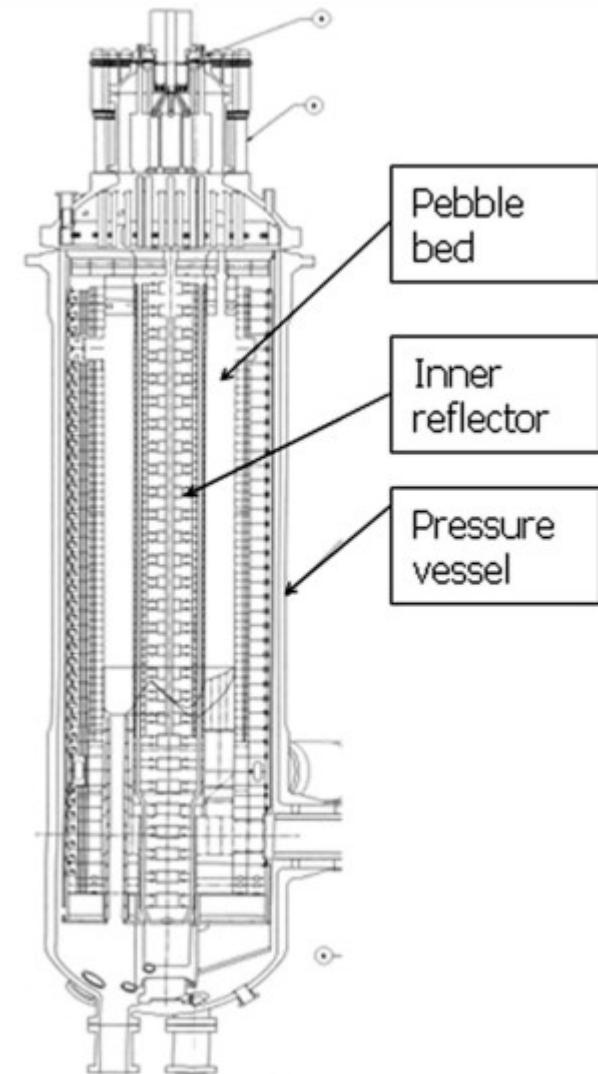
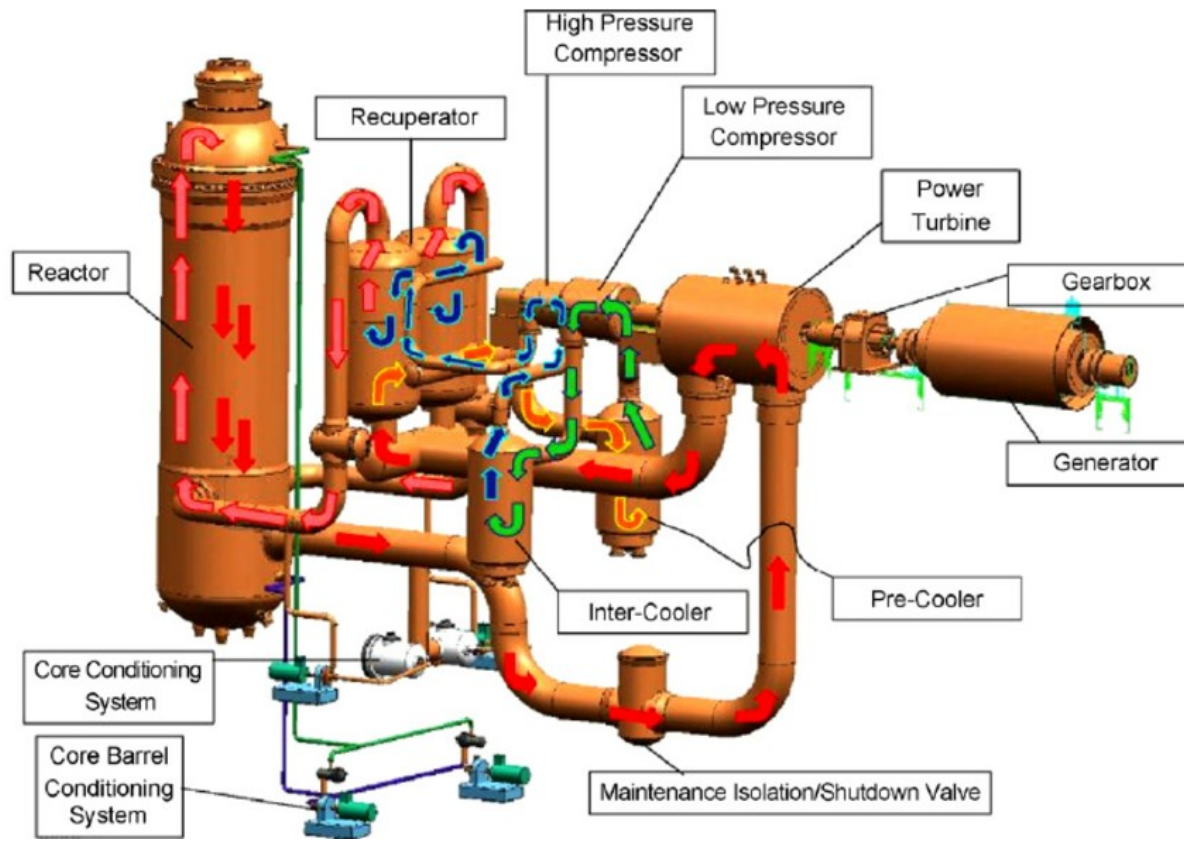


HTR-PM

Water Cooled SMRs



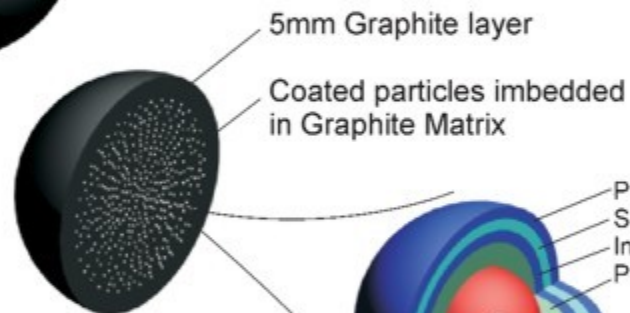
Pebble Bed Modular Reactor



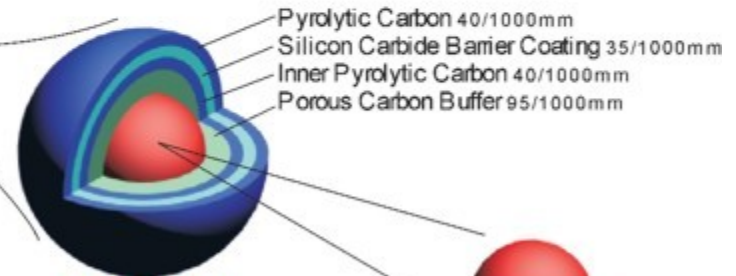
FUEL ELEMENT DESIGN FOR PBMR



Dia. 60mm
Fuel Sphere



Section



Dia. 0,92mm

TRISO
Coated Particle



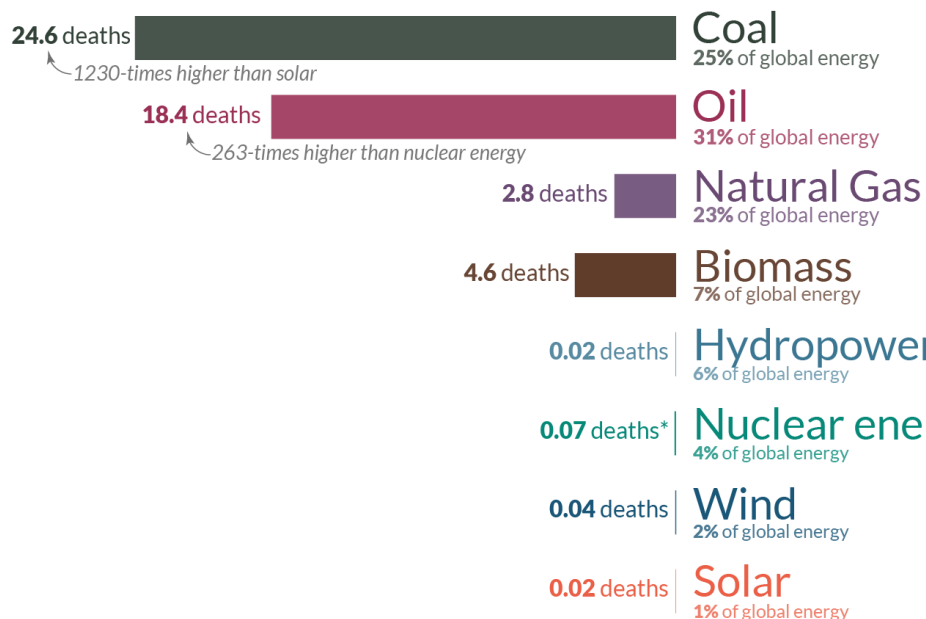
Dia. 0,5mm
Uranium Dioxide
Fuel Kernel

Final Thoughts?

What are the **safest** and **cleanest** sources of energy?

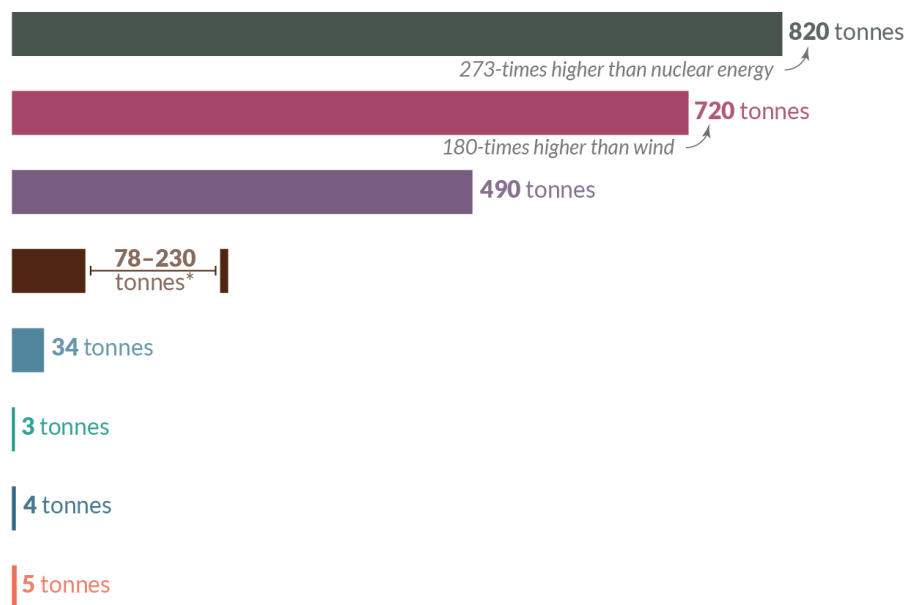
Death rate from accidents and air pollution

Measured as deaths per terawatt-hour of energy production.
1 terawatt-hour is the annual energy consumption of 27,000 people in the EU.



Greenhouse gas emissions

Measured in emissions of CO₂-equivalents per gigawatt-hour of electricity over the lifecycle of the power plant.
1 gigawatt-hour is the annual electricity consumption of 160 people in the EU.



*Life-cycle emissions from biomass vary significantly depending on fuel (e.g. crop residues vs. forestry) and the treatment of biogenic sources.

*The death rate for nuclear energy includes deaths from the Fukushima and Chernobyl disasters as well as the deaths from occupational accidents (largely mining and milling).

Energy shares refer to 2019 and are shown in primary energy substitution equivalents to correct for inefficiencies of fossil fuel combustion. Traditional biomass is taken into account.

Data sources: Death rates from Markandya & Wilkinson (2007) in *The Lancet*, and Sovacool et al. (2016) in *Journal of Cleaner Production*; Greenhouse gas emission factors from IPCC AR5 (2014) and Pehl et al. (2017) in *Nature*; Energy shares from BP (2019) and Smil (2017).

[OurWorldinData.org](https://www.ourworldindata.org) – Research and data to make progress against the world's largest problems.

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Who has already decarbonized* their electricity grid?

